REVIEWER #1
COMMENTS AND AUTHOR RESPONSES
28 SEPTEMBER 2023

Thank you for your very helpful comments on our Brief Communication. Our responses to your various points are shown in italics below:

The brief communication describes and interpretes ice-avalanche deposits from a site in Nepal. The contribution also concludes in recommendations related to monitoring and hazard risks.

My main concern with this study are the risk assessments and monitoring recommendations that are, first, not really careful, or detailed enough grounded, and second, not up to scientists, and especially not in a brief communication without space for sound and detailed assessments. I acknowledge the good will of the authors, but given the pressure or confusion such publication could put on local authorities or damage it could do (e.g. impact on tourism and thus local income), such paper should not be published in TC. In an extreme case it could result in liability issues for the involved parties. A number of details suggest this submission was not done carefully, see below details.

- ***We agree that this is not a particularly unique event (i.e., it is one of several that may occur annually in the region), but such events are not commonly reported and are rarely if ever documented. ~~Thus we have chosen to highlight a common hazard in the region while pointing out several prospective mitigation measures that could be considered to lessen the potential impacts.~~ We have also revised the paper to focus entirely on the event itself, with brief mention of possible mitigation measures confined to the Discussion section. Please consult the track changes version of our edits for further details.***

~~Likewise, and based on the collective authors' decades of experience working in the field of cryospheric hazards, it is precisely the lack of such information that is part of the problem facing governments and practitioners face in the design and implementation of effective mitigation measures. As mentioned in the Introduction, although modern technologies have enabled a more rapid identification of similar events, "…. remain unreported because of their remoteness, inaccessibility, poor communications, and/or absence of people," the current event an excellent case in point. If published, the paper would be shared immediately with KCA authorities and local communities, including the recommendations that villages such as Kampuchen begin thinking seriously about installing flood mitigation technologies such as the gabions mentioned in the paper. No pressure on local authorities, or negative impacts on the region's tourism, are envisioned, rather the exact opposite in the form of providing information and recommendations in a data deficient region is fully expected (and has been the case in numerous other community-based projects~~

~~*implemented by the authors over the years, including those funded by NSF, USAID, National Geographic, and others.*~~

I don't understand what the purpose of this paper is? It looks more like a blog (with attention to my above concerns, though). What is special with this event? The paper contains and concludes several little explained and discussed but strong statements (undagerous lake, recommendation of early warning and monitoring ...). If I don't overlook a non-searchable part of the submission, there is a substantial number of references in the reference list that I don't find in the text, and vice-versa. This adds to my impression that this submission was not done carefully enough.

Thank you again for pointing out several areas where the paper could be strengthened. We ~~*are currently preparing a*~~*have now prepared a* ***revised version of the paper which we feel will address*** ~~*most*~~ *all* ***of your concerns*** *by its focus primarily on the event itself, with other aspects such as possible mitigation measures for local villages confined to the Discussion section only. References have also been checked and are now complete.*~~*, including greater clarity describing the importance of the event, the importance of informing local people of the current status of Nupchu glacial lake, the importance of the recommendations, etc.*~~

Detail comments:

line 24: this straight and extensive monitoring advice (half of the abstract) is not up to scientists without mandate by the responsible authorities.

References to monitoring have been removed from the abstract.

~~*We disagree in part. One of the many challenges currently facing the development of effective responses to the impacts of climate change is the lack of communication between scientists and government (we assume this is what you mean by "responsible authorities"). Of course, for science to have the greatest impact, it must be accepted by local authorities and the public. But if scientists were to always wait for the mandates of "responsible authorities" many such events would go unreported. Likewise, scientists who communicate only with scientists accomplish little of use by the communities and stakeholders impacted most by such events as those described in the paper. Please see Watanabe et al. 2016 in the paper's references for further detail.*~~

62: I don't understand what the biological richness of the area has to do with the topic of the paper, ice avalanche risks.

Removed from the narrative.

~~*We agree that this sentence, as written, is not justified appropriately, and have thus deleted it. However, high biodiversity is one of the most promising assets that the KCA has in terms of its development of adventure tourism, which in turn can be impacted by climate change and catastrophic events.*~~

90: Why specifically this DEM, not e.g. the HMA DEM?

Thank you for this suggestion. As several of the co-authors agree that HMA DEM would have been the better choice, we accessed the data and mapped de DEM realizing that in the study area there are several patches with no data as you can see in the Figure below. Theses discontinuities in the data make the HMA DEM not suitable for the debris flow simulation. Therefore, we decided to continue using the DEM originally selected (ALOS-PALSAR) since according to the literature, it has the best resolution and elevation accuracy for mountain and rugged tarrains from the freely available DEMS in the study area.

Bhardwaj, A. (2019). Assessment of Vertical Accuracy for TanDEM-X 90 m DEMs in Plain, Moderate, and Rugged Terrain. The 2nd International Electronic Conference on Geosciences, 8. https://doi.org/10.3390/IECG2019-06208

Shean, D. (2017). High Mountain Asia 8-meter DEM Mosaics Derived from Optical Imagery, Version 1 [Data Set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/KXOVQ9L172S2. Date Accessed 09-25-2023.

Shawky, M., Moussa, A., Hassan, Q. K., & El-Sheimy, N. (2019). Pixel-based geometric assessment of channel networks/orders derived from global spaceborne digital elevation models. Remote Sensing, 11(3). https://doi.org/10.3390/rs11030235

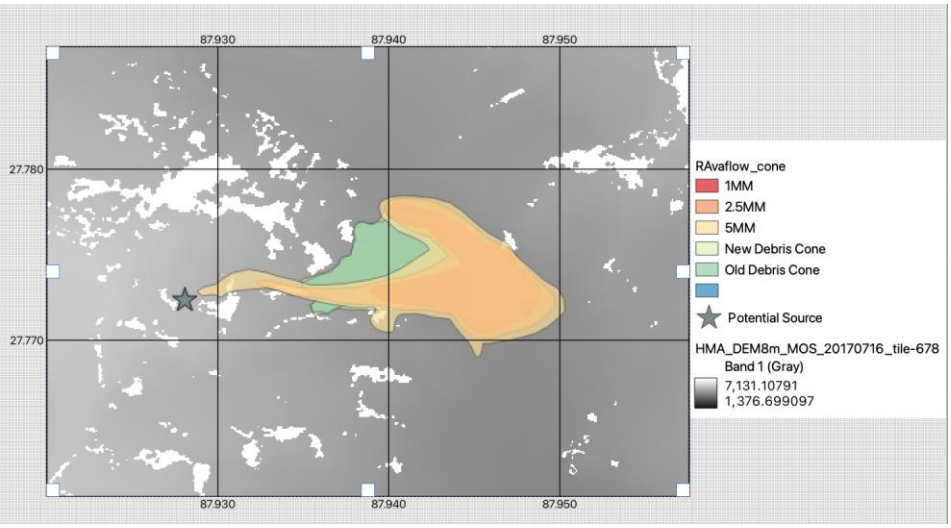
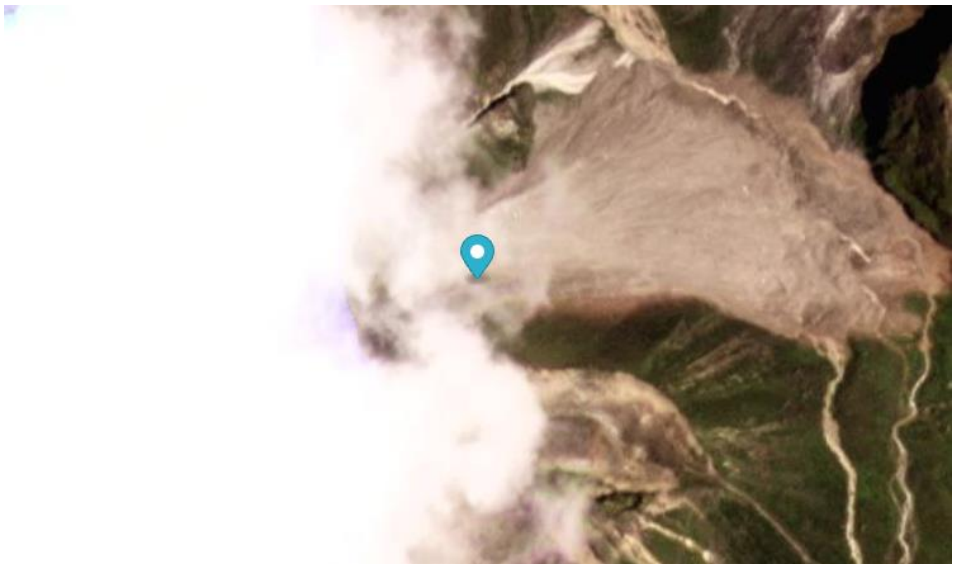


Figure XXXX: Discontinuity of the HMA DEM in the area of the debris flow119: frequency-magnitude information is just given in the figure caption. Information, more detailed, is needed in the main text.

We propose adding the following into the main text, starting at line 119: "Time series satellite images showing the periodic occurrence of surficial debris flows upon the original deposition. These appear to have accelerated in both frequency in magnitude beginning several years ago, leading up to the main event that occurred between 16 and 21 August 2022."

Fig2: is there no suitable satellite image closer after the event? Only several months later?

Indeed, the number of cloud-free images from after the event was disappointing. There are images from Aug 21, 24, 25, Sept 21, Oct 3, 8, with clouds obscuring the source area, as well as some where fresh snowfall (e.g. Oct 16) makes interpretation trickier. While we could map the distribution of the debris sheet from the earlier imagery (e.g. Aug 21), we felt it better to show a later image in which the source zone (and the changes therein) is easier to see. I have attached an example image from Aug 24.



Example Planetscope image from Aug 24

around 153: This is quite far-fetched based on a few satellite images and one avalanche event.

We propose to revise this sentence as "…These can be expected to increase in frequency as well as magnitude…." to "If these increase in frequency as well as magnitude in the coming decades within the Kanchenjunga region, they could include such events as new GLOFs, englacial conduit floods, rockfall-induced rock avalanches, and other phenomena."

around 159: Is there more risk than in the many other Himalayan valleys? Such avalanches might have happened at several other places. Are you sure this is a special event? What are your arguments for that?

It is one of many such events that occur annually in the Himalayas which are neither reported to central government authorities nor studied by scientists in both the field and laboratory. For example, only one GLOF event was in ICIMOD's records of GLOFs in the Kanchenjunga region of Nepal in 2019, when a subsequent field, lab, and oral testimony investigation revealed that 8 major GLOF events had occurred. We feel that our Brief Communication describing this event in the Kanchenjunga region will be of use to the GON's Department of Hydrology and Meteorology, ICIMOD, USAID, and other climate change within the Hindu Kushi-Himalayan region, including threatened villages such as Kampuchen.

164: You cannot mention in the conclusions, without any assessment presented in the paper, that a certain lake represents no outburst risk.

~~***The lack of danger posed by the Nupchu glacial lake is discussed in detail between lines 99 and 109.***~~

Mention of Nupchu as a potential danger has been omitted from the conclusion, which now focuses on the actual event itself.

around 184: These are pretty wide conclusions based on one local event.

~~***Thank you for this comment. We agree that, as written, these conclusions are quite broad. However, they were also facilitated and augmented by decades of community-based field and laboratory projects in cryospheric hazards and their mitigation measures in the Himalayas and Andes, including previous work by various authors of the paper. Given the space restrictions, a more lengthy discussion is not possible, but we have added an additional clause pointing to the existing body of literature. but we feel that the present revised paper addresses this concern as well.***~~

The conclusions now focus entirely on the event itself, thanks to the thoughtful comments of Reviewer #1. They now read:

Beginning in 2020, a series of small-to-medium, torrent-like pulses commenced upon a historic debris cone located approximately 2 km down valley from the lake, culminating in a relatively large avalanche event that occurred sometime between 16 and 21 August 2022. The August 2022 event deposited debris with an area of 0.6 km^2 and estimated volume in the order of 10^6 m^3. No fatalities from the event occurred because of the absence of humans and livestock in the vicinity when the event occurred. Likewise, no impoundment of the Nupchu Khola, and formation of a potentially dangerous backwater lake, occurred as a result of debris blockage, although such scenarios happen routinely in high mountain environments.

The improvement of remote area event reporting mechanisms, especially to authorities in the capital, Kathmandu, could help with the development of hazard mitigation technologies and response. Likewise, more systematic monitoring of cryospheric events by scientists, using remote sensing platforms and hazard mapping tools, could help with the development of more effective early warning systems for vulnerable communities, livestock, and adventure tourists. Ultimately, this could lead to a minimization of losses and damage due to multi-hazard events.

Brief Communication: An Ice-Debris Avalanche in the Nupchu Valley, Kanchenjunga Conservation Area, Eastern Nepal

REVIEWER #2

COMMENTS AND AUTHOR RESPONSES

28 SEPTEMBER 2023

Authors Response: Thank you very much for your thoughtful and helpful comments. We have provided our responses below each of the key points below:

Comment: This short paper describes a mass movement event in the Kangchenjunga Conservation Area. It is fairly interesting but appears to be a bit underwhelming for a mainstream journal like *The Cryosphere*. Even the Abstract describes the events as "a series of small-to-medium, torrent-like pulses" and "a comparatively large ice-debris avalanche event". Neither description suggests that the events were particularly remarkable and this is supported by the fact that the events failed to impact local infrastructure and inhabitants. As a result, although the paper is a quite interesting if short study, there is quite a lot that could have been added to this such as photographs from the site itself and, perhaps some meteorological observations or climate data. The paper could also have included some detailed risk assessments for the local village.

Response: We agree that the topic is worthy of a more comprehensive study in the future, which could include more narrative, photographs, meteorological and climate data. However, in the case of our Brief Communication, our primary objective is to highlight this style of event in this region, which has not received extensive study previously. We are constrained by the "Brief Communications" requirements: "Brief communications are timely, peer-reviewed, and short (2–4 journal pages). These may be used to (a) report new developments, significant advances, and novel aspects of experimental and theoretical methods and techniques which are relevant for scientific investigations within the journal scope; (b) report/discuss on significant matters of policy and perspective related to the science of the journal, including "personal" commentary; and (c) disseminate information and data on topical events of significant scientific and/or social interest within the scope of the journal. Brief communications have a maximum of 3 figures and/or tables, a maximum of 20 references, and an abstract length not exceeding 100 words. The manuscript title must start with "Brief communication:". Again, we thank you for your comments and will consider incorporating them in a future longer-format study.

Comment: Is there any data on the magnitude/frequency relationships of such events in this region of the Himalayas?

Response: There is a lack of information related to the magnitude/frequency of such events in the Kanchenjunga region. In fact, this study is one of only a handful of peer reviewed papers available for the region that are concerned with high magnitude/low frequency events. We feel that this situation only underscores the importance of making the information in the current paper available to a wider audience, even as a short-format Brief Communications.

Comment: What is the link between this and regional climate change? This is discussed briefly but this could be significantly expanded.

and…

Comment: The paper could make quite a nice local site example in a regional journal, but as it stands, I do not think that the paper is significant enough for TC.

Response: Thank you for these suggestions. These are important points that are worthy of further investigation but given the limitations imposed by the Brief Communications format, we are unable to expand the analysis further.

Thanks you again for taking the time to provide feedback on our Brief Communications submission to The Cryosphere.

Specific comments.

Line 67 Presumably glaciers have been receding since before then….Last Glaciation?

- ***The sentence has been modified and expanded as follows:***

Valley glaciers are largely debris-covered and have been receding since the most recent maximum during the Little Ice Age. Hooker (1854), for example, wrote in 1849 of observing glacial moraines that provided proof "…of glaciers having once descended to from 8,000 to 10,000 feet in every Sikkim and east Nepal valley…" (Hooker 1854: 166). The British alpinist Freshfield (1903: 236) writes of the "glacial shrinkage" he encountered in the Lhonak region in 1899, as well as throughout both the Nepal and Sikkim sides of the Kanchenjunga massif. Although the Kanchenjunga region received some of the earliest study, exploration, and mountaineering expeditions in Nepal by outsiders (Thapa 2009), relatively little glacier and cryospheric hazards research has been conducted to date. For example, until 2019 only one GLOF event was on record for the region (Watanabe et al. 1998; ICIMOD 2011), although subsequent research revealed that at least seven others had occurred since 1921 (Byers et al. 2020). The Nupchu valley, where the ice-debris avalanche of concern occurred, is

used seasonally for yak herding, potato farming, and tourism, with four operational tourist lodges in the village of Kampuchen as of the fall of 2022 (Figure 1).

Lines 149-154 Rather vague assessment. The relationships between such events and climate warming not always apparent, and this requires a more critical assessment. The link between climate change and GLOFs is not clear (see papers by Georg Veh).

- ***The sentence has been revised as follows:*** Still, the acceleration of torrent-like pulses of debris upon the historic debris cone since 2020 suggests that they could have been linked to contemporary warming trends, similar to larger-scale mass wasting events found elsewhere in the Himalaya (e.g., Shugar et al. 2021; Kääb et al. 2021; Taylor et al. 2023). If these increase in frequency as well as magnitude in the coming decades within the Kanchenjunga region, they could include such events as new GLOFs, englacial conduit floods, rockfall-induced rock avalanches, and other phenomena (e.g., Byers et al. 2017, 2022).Vulnerable villages, such as Kampuchen, may wish to consider the installation of preventative floodwater diversion mechanisms, such as the rock-filled gabion walls currently protecting tourist lodges in the Mt. Everest region (e.g., Rounce et al. 2017; Byers et al. 2022) using participatory processes as outlined in Watanabe et al. (2016).

Several papers in the text are not listed in the reference list, and vice versa.

The references within the text and in the reference list have been corrected. Please consult the track changes versi

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